**LETTER**

**Toward a thermal model for the Skaergaard liquidus**

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**ABSTRACT**

After a review of history, it is shown that in a comprehensive 1-atm study by McBirney and Naslund (1990), the Skaergaard liquidus temperature is linear from LZa to UZa on stratigraphic height when corrected to pressure. The augite saturation point at LZa/b has the same liquid composition in terms of plagioclase An content as the corresponding point in the Kiglapait intrusion, studied at 5 kbar by Morse et al. (2004). This temperature, 1203 °C at 5 kbar, is transformed to the Skaergaard pressure at LZa/b to a value of 1173 °C. From this fixed point, all other liquidus temperatures at Skaergaard are scaled to mean plagioclase core compositions from a detailed study by Toplis et al. (2007). All such points from LZb to UZa lie, within experimental error, on the regression from McBirney and Naslund, and the further points in UZb and UZc also agree. Plagioclase-based temperatures at the base of LZa exceed the earlier estimates by ~24 °C and imply a possible temperature of 1210 °C in the Hidden Zone. These results provide a good interim model for the Skaergaard liquidus pending further experimental study at the liquidus.

**Keywords:** Skaergaard intrusion, cumulate liquidus, experimental temperature, plagioclase cores, augite saturation, pressure correction

**INTRODUCTION**

The earliest modern thermometry for the Skaergaard intrusion began with the seminal paper of Lindsley et al. (1969), in which they established the pressure of the ferrohedenbergite-ferrohedenbergite inversion in company with tridymite, and assigned a temperature range of 980–950 °C for the crystallization of UZc at 600 ± 100 bars. The upper limit of this range may reasonably be taken as the lower limit of the liquidus.

The next group effort to establish a liquidus trend was that of Morse et al. (1980), which was clearly a bootstrapping operation, made in desperation, made only for purposes of modeling, and declared to be non-rigorous. It was thereafter a source of some amusement and chagrin that this research product became for a time the chief reference in the literature to the thermal history of the Skaergaard intrusion. Notwithstanding the imprecision of the results, the principles of how the thermometry might be approached, by finding the solidus of adcumulates, was sound, even if, as experience shows, difficult and somewhat impractical. The method was also based on plagioclase compositions as a means of interpolation. A more refined approach was not attempted because we thought McBirney was on the case. The main purpose of the 1980 paper was to constrain the intensive parameters, particularly the oxygen and silica activities of the intrusion, with a result that has had some durability.

Impractical or not, the melting of cumulates was in fact undertaken, somewhat heroically, by McBirney and Naslund (1990), and presented with great deference. This work stands as the only comprehensive experimental study to date of Skaergaard liquidus temperatures and liquid compositions. It was performed under controlled atmospheres to comport with the 1980 results, at 1 atmosphere total pressure. The liquidus temperatures were not corrected to pressure, so I make that correction here by assigning pressures at the rate of 300 bars per km and temperatures on a liquidus slope of 8 °C/kbar, a consensus value found in our laboratory work (Morse et al. 2004). I also adopt the Nielsen (2004) volume estimates as a basis for stratigraphic relations, initially with 500 m assigned to the Hidden Zone. Because these volume estimates have been variously interpreted, I show their derivation here in Table 1.

Perhaps somewhat surprisingly, all but the last two of the pressure-adjusted liquidus values given by McBirney and Naslund yield a straight-line variation of temperature with stratigraphic height having the relation \( T = -0.0382H + 1167 \), \( H \) being stratigraphic height in meters, and the intercept being the temperature at the base of LZa. The regression has correlation coefficient \( r^2 = 0.993 \) and a standard error of estimate in \( T \) of ±3 °C. Other 1-atm data have been reported in the literature, but they make no material improvement on the results of McBirney and Naslund (1990).

**WHAT’S NEW?**

The stimulus for revisiting the Skaergaard liquidus was a comprehensive study by Toplis et al. (2007) of the compositions of plagioclase cores and rims in the Skaergaard intrusion. The data for the mean composition of the cores appeared to provide a reasonable basis for extrapolating temperature. A second stimulus was the presence of good experimental thermal data at 5 kbar for the first four-phase cotectic equilibrium among olivine, plagioclase, augite, and liquid in the Kiglapait intrusion.